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ABSTRACT

This paper summarizes some of the most important findings from research that evaluated the hypothesized causes of specific reading disability (dyslexia). It first discusses the immediate causes of reading difficulties in terms of deficiencies in component reading skills that might cause such difficulties and concludes that inadequate facility in word identification caused by more basic deficits in alphabetic coding are the immediate and most basic causes of difficulties in learning to read. The paper then discusses hypothesized deficiencies in cognitive abilities underlying reading ability as basic causes of specific reading disability, and concludes that phonological skills deficiencies associated with phonological coding deficits are the probable causes of the disorder rather than visual, semantic, or syntactic deficits. Hypothesized deficits in general learning abilities are also ruled out as probable causes of reading disability. The paper concludes with a brief review of results from an intervention study that tracked the progress of children classified in first grade as impaired or normally developing readers from the time they entered kindergarten through the end of fourth grade. Findings demonstrate that only a very small percentage of children with reading impairments are afflicted by basic cognitive deficits that underlie their reading difficulties. (Contains 2 figures and 66 references.) (Author/CR)

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Research in the Study of Reading Disability:

What have We Learned in the Past Four Decades?

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Abstract

In this paper, we summarize some of the most important findings from research evaluating the hypothesized causes of specific reading disability ("dyslexia") over the past four decades. We first discuss the "immediate causes" of reading difficulties, in terms of deficiencies in component reading skills that might cause such difficulties, and conclude that inadequate facility in word identification caused by more basic deficits in alphabetic coding are the immediate and most basic causes of difficulties in learning to read. We next discuss hypothesized deficiencies in cognitive abilities underlying reading ability as basic causes of specific reading disability ("ultimate causes"), and conclude that phonological skills deficiencies associated with phonological coding deficits are the probable causes of the disorder rather than visual, semantic or syntactic deficits. Hypothesized deficits in general learning abilities (e.g. attention, association learning, cross-modal transfer etc.) are are also ruled out as probable causes of reading disability, and we conclude our discussion with a brief review of results from an intervention study we have recently completed demonstrating that only a very small percentage of impaired readers may be afflicted by basic cognitive deficits that underlie their reading difficulties.

Research in the Study of Reading Disability:

What Have We Learned in the Past Four Decades?

Introduction

The question of why some children have difficulty learning to read has been the focus of a great deal of research over the past four decades, and much has been learned about the probable and improbable causes of such difficulty. Of special interest in this very rich and prolific area of inquiry has been the impaired reader who has at least average intelligence, who does not have general learning difficulties, and whose reading problems are not due to extraneous factors such as sensory acuity deficits, gross physical or neurological deficits, socioeconomic disadvantage, and like factors. Reading impairment in such children is manifested in extreme difficulty in acquiring basic reading skills such as facility in word identification word, and it has been estimated to occur in approximately 10% to 20% of the population of school age children (Harris & Sipay, 1990; Shaywitz et al, 1992). It is often called "dyslexia", or, alternatively, "specific reading disability".

In the present paper, we summarize some of the more important findings amassed by researchers who have investigated the causes and correlates of specific reading disability. We organize our discussion under two general headings that we have somewhat arbitrarily called "immediate causes" and "ultimate causes" of reading difficulties. For present purposes, the term immediate causes will have reference to manifest deficiencies in component reading skills (e.g. word identification, letter-sound decoding, etc.) as ostensible determinants of reading difficulties. The term ultimate causes will have reference to deficiencies in reading-related cognitive abilities hypothesized to underlie reading difficulties.

Immediate Causes of Specific Reading Disability

Simply put, reading entails on-line comprehension of meaning from running text. In order to comprehend what one reads, one must be able to identify the words contained in meaningful propositions with enough accuracy and automaticity to allow computation of the meanings embodied in the text within the limits of working memory. One must also have adequate language comprehension. However, we know from studies evaluating the relationship between printed word identification and written and oral language comprehension processes that reading comprehension is impaired in an individual who has adequate language comprehenion skills but inadequate facility in word identification. Thus, it would seem that the immediate and most basic cause of difficulties in reading comprehension in beginning readers is deficiencies in word identification (Perfetti, 1985).

This possibility is given added credibility by results from regression studies conducted in our laboratory and elsewhere evaluating the skills and abilities underlying reading ability. These studies have shown that there is a developmental asymmetry in the acquisition of skill in comprehending written English such that facility in word identification carries much greater weight as a determinant of reading comprehension than do language comprehension processes at the early stages of reading development, whereas language comprehension processes carry much greater weight as determinants of reading comprehension in children at later stages (Curtis, 1980; Hoover & Gough, 1990; Vellutino, Scanlon, & Tanzman, 1994). Thus, we found that tests of word identification were much better predictors of performance on reading comprehension tests than were tests of listening comprehension in beginning and less skilled readers whereas the opposite pattern was evident in more skilled readers. Moreover, tests evaluating knowledge and application of letter-sound correspondence rules (i.e. pseudoword decoding), spelling ability, and related phonological skills such as phoneme awareness and verbal memory, were much better predictors of facility in word identification, than

were tests evaluating vocabulary knowledge, general knowledge, and syntactic processing, which were found to be better predictors of facility in listening comprehension (Vellutino et al, 1994).

In contrast, visual abilities were found to be relatively poor predictors of reading comprehension, word identification, pseudoword decoding, and spelling ability at all age levels, and the combined results, along with relevant research conducted with adult skilled readers (see Frost, 1998 for a recent review), provide very strong evidence that reading is primarily a linguistic skill. This, of course, contrasts with the intuitive and popular notion that reading is primarily a visual skill.

However, this research also shows that the acquisition of skill in beginning reading depends more heavily on the phonological components of language than on the semantic and syntactic components of language, which is predictable, given the alphabetic properties of written English. Alphabetically based orthographies are inevitably characterized by a high degree of visual similarity, and the demands made on visual memory are extraordinary. Thus, in order to reduce the load on visual memory to manageable proportions, the fledgling reader must increasingly detect, represent, and ultimately capitalize on the redundancies and regularities embedded in the orthography, and the success of this enterprise depends directly on his/her facility in alphabetic coding (Liberman & Shankweiler, 1979; 1991; Shankweiler et al, 1979; Tunmer, 1989). It, therefore, becomes necessary for beginning readers to acquire mastery of the alphabetic code, and there is now a great deal of reliable and highly convergent evidence which documents that those who have difficulty acquiring mastery of the alphabetic code also have difficulty learning to read and spell (e.g. Fletcher et al, 1994; Olson et al, 1994; Siegel & Ryan, 1984; Stanovich & Siegel, 1994; Vellutino, 1979; 1987; 1991; Vellutino & Scanlon, 1987a, 1987b; Vellutino, Scanlon, & Tanzman, 1994; Vellutino et al, 1996).

Yet, there is also a great deal of evidence that facility in alphabetic coding, itself, depends on the acquisition of phoneme awareness--that is, conceptual grasp and explicit awareness that spoken words are comprised of individual speech sounds (Liberman et al, 1974). Poor readers have been consistently shown to have difficulty acquiring phoneme awareness (Vellutino et al, 1996), but more direct evidence for the possibility that deficiencies in phoneme awareness and alphabetic coding may be causally related to reading difficulties comes from both naturalistic and controlled laboratory studies in which it was found that training that helped children acquire these skills had a salutary effect on word identification, spelling, and reading ability in general (e.g. Adams, 1990; Blachman, 1994; Bradley & Bryant, 1983; Lundberg et al, 1988; Scanlon & Vellutino, 1996; Vellutino & Scanlon, 1987a; Williams, 1980). Thus, it seems reasonable to conclude that inadequate facility in word identification is the immediate and most central cause of reading difficulties in beginning readers, and that this problem is, itself, causally related , either to inherent limitations or to experiential and instructional deficits that lead to significant difficulties in mastering the alphabetic code.

Ultimate Causes of Reading Disability

Visual Deficits

The study of basic cognitive deficits as underlying causes of reading disability has a long history (Vellutino, 1979, 1987). Etiological theories that have been proffered over the years are legion, and most have been falsified both empirically and logically. Theories implicating deficiencies in the visual system were the most ubiquitous and the most influential theories of reading disability from before the turn of the century (Morgan, 1896; Hinshlewood, 1917) up through the 1970's and 1980's, when linguistic deficit explanations of the disorder began to compete with visual deficit explanations. However, despite their popularity, the most prominent visual deficit theories had little empirical support, and confounded the visual and

verbal components of reading and spelling.

The demise of visual deficit theories was initiated in our laboratory through a series of related studies that systematically evaluated traditional and widely accepted etiological theories such as Orton's (1925) optical reversibility theory (i.e. perceiving letters and words as reversed forms), Hermann's (1959) spatial confusion theory (i.e. inherent spatial disorientation), and a variety of other theories that implicated deficits in visual processes such as visualization, visual sequencing and visual memory as basic causes of reading difficulties (see Vellutino, 1979; 1987; Vellutino & Scanlon, 1982, and Fletcher et al, in press, for reviews). In evaluating these theories, we made use of a wide variety of visual processing paradigms that were carefully designed to control for or minimize the influence of verbal coding (e.g. visual discrimination, spatial orientation, visual memory, visual learning), and we consistently endeavored to replicate given findings with independent samples of poor and normal readers.

To be brief, in virtually every study we have conducted, comparing poor and normal readers across a broad age range (most often grades 2 through 8), we found no significant differences between these groups when the influence of verbal coding was controlled. For example, we found that memory for visually similar letters and words such as **b**, **d**, **was**, and **saw** was as good in poor readers as it was in normal readers when the task required a written response rather than a naming response, which did differentiate these two groups. Even more impressive was our consistent finding of no differences between poor and normal readers on measures evaluating visual recognition and visual recall of letters and words from an alphabetic orthography with which the two groups were unfamiliar, specifically, written Hebrew. Moreover, there were no substantial differences between these groups on measures evaluating orientation and left to right processing of the letters in Hebrew words, compared with children who were learning to read and write Hebrew, whose

accuracy was greater and whose (right to left) processing strategies were different from the children who were unfamiliar with Hebrew. Research conducted elsewhere provided additional confirmation that poor and normal readers have comparable visual abilities (Vellutino, 1979, Vellutino & Scanlon, 1982; Fletcher et al, in press), and we, therefore, concluded that visual deficits of the types that had been touted in the early literature are no more prevalent in poor readers than they are in normal readers. We also concluded that certain hypothesized deficits such as Orton's optical reversibility and Hermann's spatial confusion are pseudoproblems that have no psychological reality.

Linguistic Deficits

If reading is primarily a linguistic skill, then it would seem that reading disability could be caused by deficiencies in the semantic, syntactic, or phonological components of language. For example, we have theorized that vocabulary deficits may be a basic cause of difficulties in learning to read in some impaired readers (Vellutino, 1979, 1987; Vellutino & Scanlon, 1982), and have demonstrated, in simulated reading tasks using both novel alphabetic and ideographic characters as visual stimuli, that normal as well as poor readers had more difficulty establishing connective bonds between low meaning words and the characters representing those words than between high meaning words and the characters representing those words, regardless of whether the characters were ideographic or alphabetic in nature (Vellutino & Scanlon, 1987a; Vellutino, Scanlon, & Spearing, 1995). Thus, it follows that a child who has a limited vocabulary could have difficulties in learning to identify printed words as wholes, even if he/she has adequate phonological and syntactic skills. Similarly, given the demonstrated utility of semantic and syntactic context in facilitating and monitoring word identification, especially in poor readers (Perfetti & Roth, 1981; Stanovich, 1980), it would seem that syntactic deficits could be a contributing and/or compounding

factor, if not the primary cause of word identification problems in such children.

Nevertheless, in both cross-sectional and longitudinal studies evaluating each of these hypotheses (Vellutino & Scanlon, 1987a, 1987b, Vellutino, Scanlon, & Tanzman, 1988, Vellutino, et al, 1996), we found no strong or reliable differences between poor and normal readers on tests of semantic and syntactic abilities administered at the beginning stages of literacy development (grades K-3), but did find strong and reliable reader group differences on such measures when they were administered at later stages (grades 6 and 7). These results suggest that semantic and syntactic deficits are a consequence of prolonged reading problems, rather than the primary cause of such problems (Stanovich, 1986). However, such findings do not preclude the possibility that semantic and syntactic deficits could contribute to difficulties in learning to read in any given case, and they would inevitably be a significant cause of reading comprehension problems, even in a child who has adequate facility in word identification.

In contrast to the weak support for semantic and syntactic explanations of specific reading disability in the population of children typically studied, there is now strong and highly convergent evidence in support of phonological deficit explanations of the disorder. Poor readers have been consistently found to perform below the level of normal readers on measures evaluating phonological skills such as phoneme awareness, pseudoword decoding, name retrieval, and verbal memory (see Vellutino et al, 1996 for a review), but as we indicated earlier, the most compelling evidence for a causal relationship between phonological skills deficiencies and achievement in beginning reading is provided by training studies which have documented that direct instruction designed to facilitate phoneme awareness and letter-sound mapping had a positive effect on word identification, spelling, and reading ability, in general, in both normally developing readers and in poor

readers(see earlier references). We, therefore, conclude along with numerous other investigators, that specific reading disability, in most cases, is caused primarily by phonological skills deficiencies, which may often be associated with basic deficits in phonological coding ability (Liberman & Shankweiler, 1979, 1991). Phonological coding deficits could contribute, not only to difficulties in mastering the alphabetic code, but also to difficulties in establishing connective bonds between printed words as wholes and their visual counterparts (Vellutino & Scanlon, 1987a).

Deficits in General Learning Abilities

We should also mention that, in addition to deficiencies in visual and linguistic abilities, specific reading disability has been variously attributed to dysfunction in selective attention (Douglas, 1972), associative learning (Brewer, 1967; Gascon & Goodglass, 1970), cross-modal transfer (Birch, 1962), serial-order processing (Bakker, 1972), and pattern analysis and rule learning (Morrison & Manis, 1982). Yet, as we have stated elsewhere "dysfunction in one or another of these rather basic and general learning abilities would seem to be ruled out as significant causes of the disorder in a child who has at least average intelligence and who does not have general learning difficulties, given that all of these cognitive abilities are entailed in virtually all tests of intelligence, and are most certainly entailed in all academic learning" (Vellutino et al, 1996, p. 602). More important, however, is that each of these hypotheses has also been discredited by empirical research. This research has been summarized elsewhere and will not be reviewed here (Vellutino, 1979, 1987; Vellutino & Scanlon, 1982; see also Katz et al, 1981, 1983). It will suffice to point out that most of the studies reporting differences between poor and normal readers on measures of these general learning abilities did not control for reader group differences in verbal coding ability and/or working memory processes that might be affected by verbal coding deficits, and in subsequent studies which did

implement such controls, group differences on measures of these abilities were generally eliminated[3].

Constitutional versus Experiential and Instructional Causes of Reading Difficulties

Specific reading disability, as an etiological construct, incorporates the assumption that children who qualify for this diagnosis using exclusionary criteria such as those outlined earlier, suffer from basic cognitive deficits of constitutional origin. Empirical support for this possibility is seminal and suggestive, if not always conclusive, and comes from results obtained in genetic, neuroanatomical, and psychophysiological studies, which, collectively, provide some reason to believe that poor and normal readers have structurally and functionally different architecture for processing spoken and written language(See Vellutino et al, 1996 for a review). However, as pointed out by Clay (1987), virtually all reading disability research has been compromised by the failure to control for the child's educational history, given that the adverse effects of inadequate pre-reading experience and/or inadequate instruction can often mimic the effects of basic cognitive deficits, and lead to classification of a perfectly normal child as reading disabled. Consider, for example, that the acquisition of skills such as phoneme segmentation and letter-sound decoding can be greatly influenced by the type of reading instruction to which a child has been exposed. Yet, it is commonly assumed that difficulties in acquiring one or both of these skills is a manifestation of basic deficits in phonological coding.

Thus, to further evaluate the possibility that reading difficulties, in at least some impaired readers could be caused, in part, by basic cognitive deficits, we conducted a longitudinal study that incorporated an intervention component (daily one-to-one tutoring), and we tracked children classified in first grade as impaired or normally developing readers from the time they entered kindergarten through the end of fourth grade, that is, before and

after they were classified, and before and after intervention. Intervention was initiated in mid-first grade, and was terminated either at the end of first grade or in the middle of second grade, depending on the child's progress. Given results obtained in previous intervention studies (Clay, 1985; Iversen & Tunmer, 1993; Pinnell, 1989; Wasik & Slavin, 1993), we expected that most but not all of the tutored children would be successfully remediated, and we were especially interested in comparing the entry level skills and cognitive profiles of children who were the most difficult to remediate, with those of children who were readily remediated, relative to normally developing readers. We also expected that the entry level skills of the impaired readers would be uniformly deficient, but from the convergent evidence implicating phonological coding deficits as a basic cause of reading difficulties in some impaired readers, we predicted that the children who were the most difficult to remediate would perform below the children who were readily remediated, and below the normal readers as well, on measures evaluating phonological skills such as phoneme awareness, pseudoword decoding, short term verbal memory and name retrieval. We did not expect these groups to differ on measures evaluating semantic, syntactic, and visual skills. These predictions were confirmed.

First, we found that relative to normally developing readers, entry level literacy skills such as letter naming and phoneme awareness were deficient in the group of kindergarten children identified as impaired readers in first grade. Second, almost seventy percent (67.1%) of the tutored children were brought to within the average range of reading ability in only one semester of remediation, and the majority maintained this level of functioning through the end of third grade (fourth grade data being analyzed; see Figures 1 and 2). Third, the children who were found to be the most difficult to remediate performed well below the normal readers, and quite often below the children who were readily remediated on kindergarten, first,

and third grade tests evaluating phonologically based skills such as those mentioned previously. In addition, the children who were readily remediated often performed as well as the normal readers on such tests. However, there were no significant differences among any of the groups on the semantic, syntactic and visual measures. Finally, contraindicating the use of IQ scores to identify disabled readers or to predict reading achievement in beginning readers, we found that the tutored groups did not differ on any of the intelligence tests, nor did they differ from an average IQ normal reader group on these tests. Moreover, the average IQ normal reader group did not differ from an above average IQ normal reader group on any of the reading tests, except for a test of reading comprehension, on which these two groups did differ.

-Figures 1 and 2 here-

These results are quite in keeping with Clay's (1987) contention that reading difficulties in beginning readers are, in most cases, caused by experiential and/or instructional deficits, rather than by basic cognitive deficits. Indeed, the impaired reader sample we initially identified in first grade, using exclusionary criteria such as those typically used to identify "disabled readers" in such research, represented approximately 9% of the (available) population from which these children were drawn. Yet, the impaired readers who continued to qualify for this diagnosis after only one semester of remediation represented only 1.5% of the population from which these children were drawn, which is a far cry from the 10% to 20% figures that have emerged as estimates of the incidence of reading disability in the relevant literature (e.g. Shaywitz, et al, 1992). Nevertheless, the cognitive profiles of the children who were difficult to remediate, compared with those of the children who were readily remediated and with those of the normal readers, suggest that reading difficulties in some impaired readers may be caused, in part, by basic cognitive deficits of constitutional origin, and the

ultimate origins of such deficits warrant continued research in the area.

Summary and Conclusions

To summarize, we have learned much about both immediate and ultimate causes of reading difficulties in otherwise normal children over the past four decades. It is clear from the relevant research that reading is primarily a linguistic skill, contrary to the once popular notion that it is primarily a visual skill. And, because of the structural properties of an alphabetic system, it is also clear that linguistic abilities are themselves differentially weighted in reading development such that phonological skills carry greater weight as determinants of beginning reading ability than do semantic and syntactic skills, whereas semantic and syntactic skills carry greater weight than do phonological skills in more advanced readers. It follows, and the evidence confirms, that inadequate facility in word identification constitutes the immediate and most basic cause of reading difficulties. Moreover, there is reliable and highly convergent evidence that word identification problems, themselves, are causally related to deficiencies in phoneme awareness and phonological decoding, which lead to difficulties in establishing connective bonds between a word's spoken and written counterparts.

As regards ultimate causes, the research strongly suggests that reading difficulties, in at least some impaired readers, may be caused by basic deficits in phonological coding, which are believed to account for the reliable and robust differences observed between poor and normal readers on measures of phonologically-based skills such as phoneme awareness, phonological decoding, verbal memory, and name encoding and retrieval. Semantic and syntactic deficits do not appear to be a primary cause of reading difficulties in otherwise normal children, but they are a likely consequence of longstanding reading disorder. The research has also established that reading difficulties are not caused by visual deficits of the types variously

proposed over the years. Contrary to popular belief, impaired readers do not see letters and words in reverse, nor do they suffer from inherent spatial confusion or other visual anomalies of the types proposed in the early literature. There is also no reason to believe that deficiencies in general learning abilities such as attention, association learning, cross-modal transfer, serial memory, pattern analysis, and rule learning are basic causes of reading difficulties in impaired readers who do not have general learning difficulties. Etiological theories which implicate deficits in such abilities as causally related to reading difficulties can be ruled out on logical grounds alone, and they have not fared well in empirical research.

Finally, recent intervention studies have clearly demonstrated that reading difficulties in most beginning readers are not caused by basic cognitive deficits of constitutional origin, from which it can be concluded that current estimates of the incidence of reading disability are greatly inflated. However, an intervention study that we have recently completed provides reason to believe that a very small percentage of impaired readers may well be afflicted by basic cognitive deficits, especially phonological deficits, that lie at the root of their difficulties in learning to read. These and other findings we have discussed have obvious implications for the diagnosis and remediation of reading disability, but these are topics for another symposium.

Footnotes

Footnote 1

We should point out that reading disability has also been attributed to visual tracking problems associated with oculomotor deficiencies (Getman, 1985), as well as to visual masking effects associated with a hypothesized deficit in the "transient visual system" (Badcock & Lovegrove, 1981; Breitmeyer, 1989; Lovegrove, Martin & Slaghuis, 1986). The visual tracking hypothesis has been discredited by well-controlled eye movement studies finding no differences between poor and normal readers on visual tracking of non-verbal stimuli (Olson et al, 1983; Stanley et al, 1983). However, the transient system hypothesis has some empirical support, and warrants further comment.

The transient system is a functional component of the visual system that is operative during saccadic movements of the eyes, and it is believed to be responsible for inhibiting the visual trace that normally persists for a short duration (approximately 250 milliseconds) after a visual stimulus has been terminated. It has been suggested that poor readers suffer from a deficit in the inhibitory function of the transient system, producing a visual trace of abnormal longevity that creates masking effects and, thus, visual acuity problems when such children are reading connected text. Lovegrove and his associates have shown that poor and normal readers process high and low spatial frequency grids differently, and that they have different contrast sensitivity functions, such that the poor readers require greater luminosity than the normal readers for distinguishing low frequency grids (Badcock & Lovegrove, 1981; Martin & Lovegrove, 1984). However, as pointed out by Hulme (1988) and, more recently by Fletcher et al (in press), the trace persistence theory of reading disability predicts that poor readers should be impaired only when they are reading connected text, and not when they encounter printed words one at time under foveal vision conditions. Yet, we know that poor readers find it as difficult to identify printed words one at a time under

foveal vision conditions as to identify them when they are reading connected text. Furthermore, there is no evidence that poor readers experience visual acuity and visual masking problems under normal reading conditions. It should also be pointed out that the poor readers evaluated in these studies were typically found to have phonological deficits which have been shown, in empirical research, to be causally related to reading difficulties, unlike transient system deficits, which have not been shown to be causally related to readng difficulties. In addition, a significant number of normal readers were also found to have transient system deficits in the studies conducted by Lovegrove and his associates. We, therefore, doubt that visual trace persistence associated with transient system deficits is a significant cause of reading disability, although it might well be a reliable correlate of the disorder, and perhaps even a useful biological marker.

Footnote 2

We should also mention two other etiological theories which have emerged in the extant literature, specifically, Tallal's (1997) temporal order perception deficit theory and Wolf's "double deficit" theory. According to Tallal (1997), reading problems are part and parcel of general language deficits caused by difficulty in perceiving temporal order in rapidly changing auditory stimuli (e.g. changes in pitch, formant transitions etc.). Such difficulty is said to impair phoneme discrimination, and, thus, the acquisition of phoneme awareness and facility in alphabetic coding. According to Wolf (1997), reading problems may occur, either because of one of two basic processing problems or because of the co-occurence of the two (hence the "double deficit" notion). Along with other theorists, Wolf (1997) suggests that some poor readers may be afflicted by by phonological coding deficits which impair the child's ability to acquire phoneme awareness and alphabetic coding skills. This aspect of Wolf's theory is consistent with much of the research cited previously. The second type of deficit is identified as a

"timing" (or speed of processing) deficit in sequential processing of printed words, which is believed to impair the child's ability to encode and integrate the semantic, syntactic, phonological, and orthographic features of printed words.

Interestingly enough, these theories have in common the foundational assumption that at least some poor readers require more time for stimulus processing and resolution, and that the difficulty in those so afflicted may transcend sensory modalities. But, whereas Talla believes that stimulus resolution problems have their primary effects on phoneme discrimination, phoneme awareness, and alphabetic coding, Wolf believes that stimulus resolution problems have their primary effects on timely integration of printed word features, and, thereby, on name encoding and retrieval. Because both of these theories are controversial, and because studies evaluating them have, to date, yielded conflicting results, we have elected not to discuss them further.

Footnote 3

To cite one example, Birch (1962) hypothesized that reading impaired children may be encumbered by a developmental lag in the establishment of cross-modal transfer, which, he intuited, would impair their ability to represent the same information in two sensory-based systems, as in learning to read. Initial support for this theory was provided by Birch and Belmont (1964) who observed that poor readers performed below the level of normal readers in matching auditorily presented rhythmic patterns with visual representations of those patterns. Because this task confounds cross-modal transfer with working memory and verbal coding ability, we conducted a series of studies that compared poor and normal readers on both intramodal (visual-visual; auditory-auditory) and intermodal (visual-auditory) non-verbal learning tasks that minimized the influence of verbal coding ability. We also compared these groups on visual-verbal learning tasks, and we found that poor

readers performed below the level of the normal readers only on the visual-verbal learning tasks(Vellutino & Scanlon, 1982; Vellutino, 1987). These findings are at variance with Birch's cross-modal explanation of reading disability. They are also at variance with etiological theories which suggest that deficits in association learning or attention are root causes of reading disability, given that all of the tasks we used in these studies involved paired associates learning and required the utmost in attention and concentration. The data are more in keeping with verbal deficits explanations of the disorder.

We might also point out, parenthetically, that Birch's cross-modal theory of reading disability was derived from the more basic assumption that cross-modal transfer is a developmental phenomenon that is not established until early childhood (Birch & Lefford, 1963). However, this assumption has since been obviated by infant research which shows that perception of equivalences across modalities is present either at birth or shortly after birth (e.g. Gibson, 1969; Bryant, 1974; Meltzoff & Kuhl, 1994). Thus, the theory is no longer viable.

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Figure 1. **Growth Curves for Mean Raw Scores on the WRMT-R Word Identification Subtest for Normal Readers and Tutored Poor Readers**

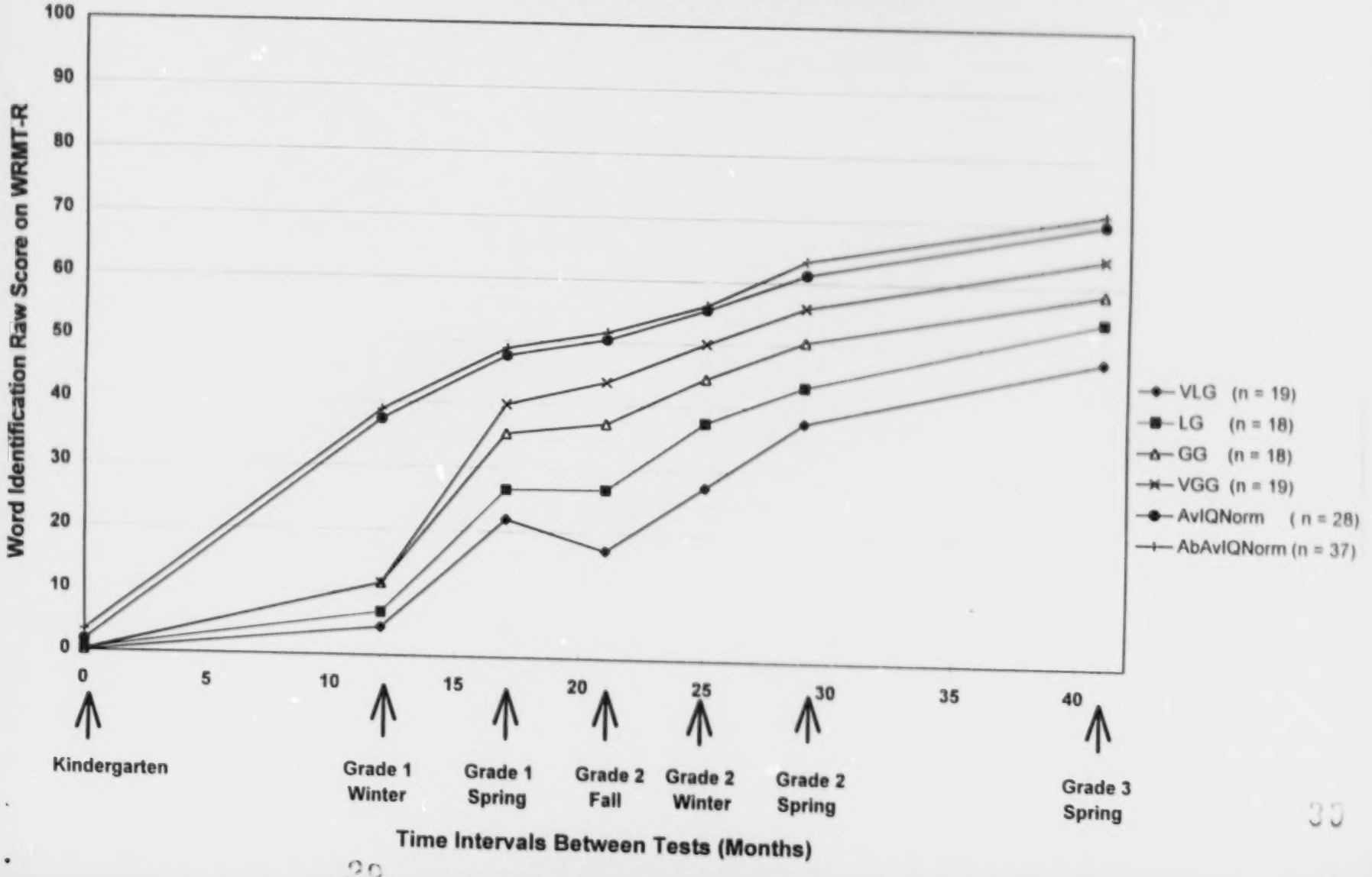

Figure 2. **Growth Curves for Mean Raw Scores on the WRMT-R Word Attack Subtest for Normal Readers and Tutored Poor Readers**